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Application of ATR spectroscopy in astrobiological search for life

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Abstract

We propose to use ATR-spectroscopy technique in search for signs of extra-terrestrial life. Such an experiment – "**MATROS**" – was proposed by us for Europa (jovian satellite) lander. It is quite possible, that some protein-based microorganisms exist in viable or anabiotic state in the under-crust Europa ocean (like they live in ancient terrestrial ices and deep permafrost [1]).

Biopolymers (proteins, DNA/RNA, carbohydrates, lipids…) inside microbes have characteristic IR bands detectable in a sample placed onto ATR-prism.

Minimal spectral range needed is 5.5–11 μm, spectral resolution is about 10 cm^{-1}, mass of the instrument is about 2 kg (mass of sample delivery system is not included).

The technique

ATR-spectroscopy technique (see Fig. 1) is widely used in laboratories. ATR-spectrum is a sort of absorption spectrum of a sample contacting an ATR-prism. Simplicity of specimen preparation is an advantage of this method: one just needs to put the specimen in contact with ATR-prism.

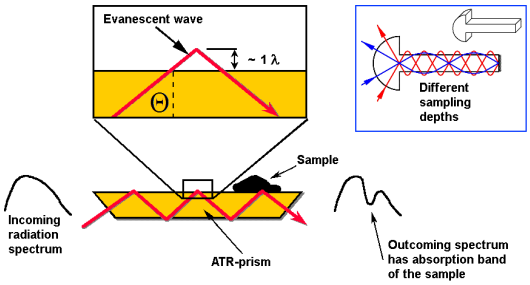

Fig.1. Basics of Attenuated Total Reflection (ATR) spectroscopy. See [2] for more details

Only a thin layer of the sample (about one λ thin) contributes to ATR-spectrum. However, it is possible to vary depth of ATR-sampling with factor 2–3 by changing AOI (Θ) and/or material (i.e., *n*) of the prism. This allows to perform a kind of layer-by-layer analysis of the sample.

Distinguishing bio-cells from mineral particles

The ice sample drilled out from Europa surface will most probably include also mineral particles. The latter may, in principle, have absorptions at the same wavelengths, as biopolymers do.

Distinguishing from mineral bands is achieved by: 1) layer-by-layer analysis, 2) dichroic ratio measurements and 3) cultivation of bacteria directly on ATR-prism.

Layer-by-layer analysis

ATR-spectra on fig. 2 (see [3]) exhibit IR absorptions characteristic for ***all*** bio-cells: «Amide-1» & «Amide-2» bands of proteins, carbohydrates and DNA/RNA bands. The latter band appears when ATR-sampling reaches cell's central area, where DNA is located. So, such a spectral behavior indicates presence of bio-cells, besides minerals.

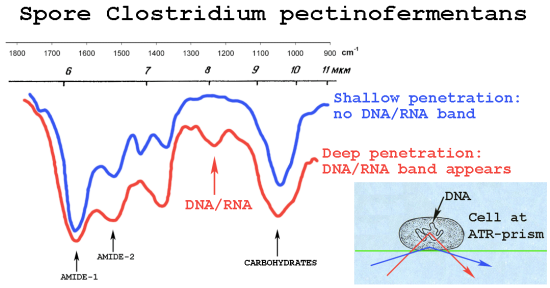

Fig. 2. Biopolymers have characteristic IR bands, e.g. ***all*** proteins show Amide-1 & -2 bands. Blue curve: only cell membrane is sampled and DNA/RNA band is absent. Red curve: central area is also sampled, so this band appears.

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Dichroic ratio

Dichroic ratio R (= $A_{\parallel}/A_{\perp}$) equals 2.0 for ATR-spectra of isotropic materials [2], including mineral powders. Biopolymers located in cell membranes introduce anisotropy and R may differ strongly from 2 [3]. So, if the measured R differs from 2, it may result from presence of bio-cells, viable or anabiotic.

Cultivation of bacteria directly on ATR-prism

Quantity of bio-cells in the drilled sample may be rather small, so a huge integration time may be needed for reliable registration of bio-bands. But we may provide conditions (e.g., thermal) for bacteria *proliferation* directly on the ATR-prism surface. The more cells on the prism – the more energy they absorb from the evanescent wave, so we'll see progressive deepening of the bio-bands.

We have tried this method in laboratory, with positive result – see fig.3. Europa's microorganisms (if they exist), once heated to 280–300 K, may exhibit growth of explosive temper simplifying detection of bands deepening.

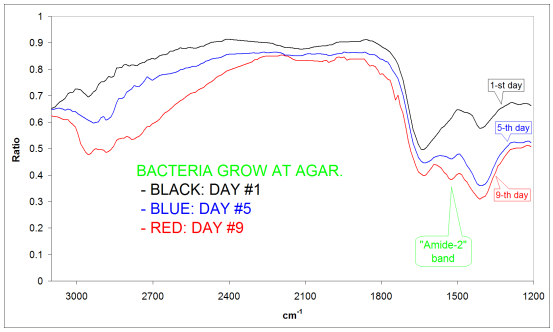

Fig. 3. Cultivation of bacteria directly on ATR-prism surface. Amide-1 band appears and progressively deepens while cells proliferate

Conclusions

ATR-spectroscopy technique had been used in laboratories for half a century but so far was never applied in planetary missions. Numerous advantages of this contact method promise great future for experiments based on it. Investigations may be focused also on aerosols (e.g., for balloon missions), minerals, different precipitation, etc.

References

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[3] Duda V., Korolev Yu. et al. (1978) *Microbiology*, 47, 750–755.